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Specification

Methods for the Qualitative Evaluation of a Material with at Least one Identifying Characteristic

The invention relates to methods for the qualitative evaluation of a material with at least one identifying characteristic in accordance with the preambles of claims 1, 2 or 3.

Camera systems are increasingly employed in the printing industry in connection with various applications, for example in inspection systems, path monitoring systems or registration measuring systems, wherein these systems are arranged at a printing press or a machine which processes material to be imprinted. Moreover, there is the requirement that these systems should perform their functions "in-line", integrated into the working process of the printing press or of the machine processing material to be imprinted, which represents a considerable challenge to the respective camera system because of the large amount of data provided by the camera system and the rapid process speed of the printing press or of the machine processing material to be imprinted, for example for obtaining a dependable evaluation, preferably of each identifying characteristic, even of identifying characteristics which are difficult to identify by spectral photometry, in spite of the high transport speed of the material, during the short time available for making the evaluation in the course of a quality control. Electronic image sensors are often used in such camera systems for recording images, in particular color cameras with an image

sensor consisting of a CDC chip, whose light-sensitive pixels provide an output signal, for example in three separate signal channels, mostly for the colors red, green and blue, corresponding to the color recorded in the observed range.

A problem of known camera systems in connection with testing colored material, in particular material imprinted in colors, consists in that the image data provided by the color cameras often do no correspond to the color perception of the human eye. Unprocessed image data from these color cameras are insufficient regarding color balance, brightness, contrast and color tone reproduction in view of the color match corresponding to the human color perception. The main reason for this problem, besides the insufficiencies of lenses and illumination devices, is the spectral sensitivity distribution of the color cameras employed. If the sensitivity distribution of the color cameras employed does not match the sensitivity distribution of the human eye, this results in that in the course of subsequent further processing, for example when displayed on a color monitor, the image data provided by the color cameras lead to a false visual impression, so that during checking a reasonable qualitative evaluation of the imprinted material is already hardly possible for this reason alone.

Because of previous production processes it can occur that the position of a detection characteristic to be evaluated during the checking process varies in certain tolerance limits within a defined expected range. For example, the position of a window thread, such as is used for example in connection with bills or stamps, in relation to the print image of the bills or stamps on a printed sheet can

vary because of the properties of the production process for producing the window thread. Such basically tolerable position deviations of certain identifying characteristics can generate a malfunction report in inspection systems, since a print pattern defined as a reference value is compared sequentially print position by print position with the actual printed image, so that deviations in the position of identifying characteristics are detected as errors, although they are not.

For example, a method is known from DE 196 13 082 A2, wherein the imprinted material, for example a printed sheet imprinted with bills and provided with a silver thread, hologram or kinegram, is illuminated by an illuminating device in such a way that the light reflected by the imprinted material enters a photoelectric sensor. The image taken by the photoelectric sensor can thereafter be evaluated in an evaluating device, for example in a standard computer with suitable evaluation software, and checked for printing errors. However, in this case it is a requirement for the evaluation that an identifying characteristic whose position varies has a sufficiently high reflecting capability, for example in that it is embodied as a shiny silver thread. Accordingly it is disadvantageous that, after having been recorded by means of the photoelectric sensor, identifying characteristics whose image properties do not differ sufficiently strongly from the image properties of the remaining print image, such as is the case for example with colored window threads, cannot be detected by the evaluation device with sufficient reliability.

A method for the qualitative evaluation of a material with at least one identifying characteristic is known from DE 101 32 589 A1, wherein an image of the material to be evaluated is recorded by an image sensor and the geometric contours and/or the relative arrangement of several identifying characteristics of this image are evaluated in respect to each other in an evaluation device.

A method for signal evaluation of an electronic image sensor in connection with detecting the patterns of image contents of a test body is known from post-published DE 102 34 086 A1, in which a decision regarding the assignment of the test body to a defined class of test bodies is made.

A measuring arrangement for identifying valuable objects by means of digital image analysis is known from DE 198 02 781 A, wherein a narrow-band excitation light source, for example a tunable laser, illuminates a selected location area of the object with light within a narrow frequency range, wherein light reflected by the object, or an emission induced in the object because of its being exposed to radiation, is for example detected by a photometrically calibrated CCD camera having a multitude of pixels, is digitized and is forwarded to a computer in the form of a data set characterizing each pixel and stored in a memory, wherein the photographically detected object can also be additionally surveyed, so that information regarding a geometric arrangement of various objects, their distance from each other or the depth of their relief structure, can be added to the data set. The data set prepared from this image detection can be made available, for example via the

internet, for a comparison of this data set with a data set prepared for another object in order to check the other object at the different location for agreement with the first object, i.e. the original, and therefore regarding its genuineness.

An arrangement for the classification of a pattern, in particular of a bill or a coin, is known from CH 684 222 A5, wherein a multi-stage classification system, capable of learning, sequentially performs at least three tests on a pattern by comparing characteristic vectors with vectorial desired values, wherein a light source illuminates the pattern and a sensor measures the radiation reflected by the pattern at discrete points in time.

Customarily, methods for pattern recognition determine similarities such as, for example, distance measurements on segmented objects, or their calculated global threshold distributions. These methods are based on translation-invariant initial spectra. However, situations often occur in real life, such as object displacements underneath the recording system, for example, different backgrounds during the recordings, or aliasing effects, so that in many cases a direct comparison of these initial spectra with stored reference values cannot be performed.

It is the object of the invention to create methods for the qualitative evaluation of a material with at least one identifying characteristic, which can be employed in the printing industry.

In accordance with the invention, this object is attained by means of the characteristics of claims 1, 2 or 3.

The advantages to be obtained by means of the invention lie in particular in that a material, in particular an imprinted material with at least one identifying characteristic, can also be dependably qualitatively evaluated if the color image taken of the material, in particular the identifying characteristics, has optical properties which cannot be sufficiently identified by means of spectral photometric methods alone. Since the proposed method does not require that the material to be evaluated qualitatively has a distinctive reflection capability, it is possible to define practically any arbitrary, optically detectable property or condition of the material as its identifying characteristic, so that a clearly expanded application range of the method results. It is therefore possible to decide in what the identifying characteristics should consist as a function of the application. The test is solely directed to there being an optically recognizable difference at all between the identifying characteristic and its surroundings. This difference is utilized for qualitatively evaluating the material, which can also include, for example, its identification or a test of its genuineness.

In particular, the proposed method leads to good results if it is furthermore assumed that the position of the identifying characteristic varies within an expected range determined by tolerance limits. Moreover, in respect to color hues, fullness and brightness, the colors picked up by the image sensor are arranged sufficiently accurately in a color range which corresponds to the color perception of the

human eye, so that the material is reproduced by a display device, for example a color monitor, in the form of a color image in such true colors as if the material were inspected directly by a human eye, so that a dependable qualitative evaluation of the material, and therefore also of its identifying characteristics, becomes possible by means of the color image.

Here, the so-called CIELAB color range, which has found wide application in printing technology, for example, is suitable as the color range. An important characteristic quantity of color deviation in the CIELAB color range is provided by the color distance Delta E between the reference variables and actual values of the parameters L, a and b, which characterize the CIELAB color range, wherein the parameter L identifies the brightness, a the red-green value and b the yellow-blue value. These parameters are also called CIE values. Further characteristic quantities are the color hue difference Delta H and the fullness difference Delta C, wherein the color hue difference Delta H in particular is important as a characteristic quantity in multi-color printing, because an off color is subjectively perceived to be more disturbing than a fullness difference Delta C indicating a brightness difference. Thus, for example, a color distance Delta E of a value 1 means a non-visible color difference, of 2 a small difference, of 3 a recognizable difference. of 4 a clear difference and, starting at 5, a large difference. The value range of the CIE values a and b respectively extends from -100 for green or blue to +100 for red or yellow, the value range for brightness L from 0 (black, total absorption) to 100 (white,

total reflection). The value triplet L = 50, a = 0, b = 0 identifies a neutral medium gray.

Three types of cones (S, M, L) exist in the human eye, which absorb light entering in different spectral ranges. The maximum absorption of the S-type cones lies in the blue range, namely at 420 nm. The M-type cones maximally absorb in the green spectral range, namely at 534 nm. The maximum of the L-type cones lies at 564 nm in the yellow/red spectral range. Perception by means of three cone types is called tri-chromatic perception. The individual color perceptions are triggered by stimulation of different strength of the individual cone types. An identical stimulation of all cone types leads to the perception of the color white.

However, color perception phenomena, such as color antagonism and color constancy, for example, cannot be explained by the tri-chromatic perception model. Color antagonism means that certain colors can never be seen in transition, i.e. that no color transition between these colors is possible. Colors demonstrating color antagonism are called compensation colors or complementary colors. To be cited among these are the color pairs red/green and blue/yellow, as well as black/white. In color constancy the different spectral distribution of the light which, for example, is a function of the weather or daylight conditions, is compensated.

Hering developed the compensation color theory in 1920 for explaining these color perception phenomena in a way different from the classic tri-chromatic color model. The compensation color model assumes that the cones are arranged in receptive fields, namely in blue/yellow fields and

red/green fields. In this case, receptive fields are understood to be neurons, as well as the manner in which the stimulation of the cones is further processed by the neurons. Two types of receptive fields are substantially responsible for color perception. The first receptive field obtains its input from the L- and M-cones, the second receptive field from the S-cones, together with differently weighted stimulations of the L- and M-cones. It is assumed that a subtractive color mixture is performed on the level of the neurons or receptive fields for stimulating the cones.

The RGB model is the tri-chromatic model for describing additive color images most used in technology. In the RGB model the color range is described by the three basic colors red, green and blue. With this model it is particularly disadvantageous that the description performed by means of the RGB model does not correspond with the perception of the human eye, since the behavior of the human perception in particular, i.e. the perception through the senses, is not being taken into consideration.

As a rule, electronic image sensors, in particular CCD chips for color cameras, have a multitude, for example a million or more, of light-sensitive pixels, which are for example arranged in a matrix-shape, each of which as a rule provides a first electrical signal corresponding to the colored light recorded in the observed area and correlated with the color image, which is split up, for example, in three signal channels which are separated from each other, wherein at the time of the observation each signal channel makes available a portion of the first electrical signal mainly corresponding to one of the basic colors red, green

and blue. Such a signal is called an RGB signal. Usefully a spectral sensitivity of each signal channel (R, G, B) is matched to the spectral sensitivity of the human eye, for example R = red to 564 nm, G = green to 534 nm and B - blue to 420 nm. Also, the first electrical signal in its entirety is matched regarding hue, fullness and brightness to the color perception of the human eye. Accordingly, a color image recorded by means of such a color camera is composed of a multitude of image points.

The method in accordance with the invention is now distinguished in that a second electrical signal is obtained from at least one reference image and is stored in a data memory, wherein the second electrical signal constitutes at least a reference variable for the first electrical signal, that, by means of a comparison of the first signal with the second signal, at least the color image of the identifying characteristic is checked for a color deviation from the reference image, and/or the identifying characteristic for its association with a defined class of identifying characteristics, and/or with a defined geometric contour and/or a relative arrangement with at least one further identifying characteristic of the material, each by means of a comparison of the first signal with the second signal for having reached the reference variable or an agreement therewith. For increasing the test dependability, the material and/or its identifying characteristic is preferably simultaneously always checked in regard to at least two of the above mentioned criteria. To this end, at least two of the tests of the color image, in particular the test of the identifying characteristic for a color deviation from a

reference image, and the test of the identifying characteristic for its association with a defined class of identifying characteristics or with a defined geometric contour or a relative arrangement with further identifying characteristics of the material preferably take place at the same time in parallel test procedures which run independently of each other. By means of the proposed method, an evaluation of imprinted material in a running printing process of a printing press, or in a running work process of a machine which further processes the imprinted material, is possible for the quality control of this material, because of the resultant test dependability and because of the testing speed with which the performance of the method takes place. This material constitutes in particular high-quality printed products which, for example for security reasons, require very careful testing and on which great demands are made, for example regarding the stability of their condition in regard to print technology, i.e. bills and stamps in particular.

Testing the color image for color deviation from the reference image preferably takes place in that the portion of the first signal from the color image made available in the first signal channel is linked by means of a first calculation prescription with the portion made available in the second signal channel, wherein an output signal from a first compensation color channel is generated in that the portion of the first signal from the color image made available in the third channel is linked with the portions in the first and the second signal channel by means of a second calculation prescription, by means of which an output signal from a second compensation color channel is generated, and

that the output signals of the compensation color channels are classified by being compared with reference variables.

Testing the identifying characteristic regarding its association with a defined class of identifying characteristics is preferably performed in that the first electrical signal made available by the image sensor is converted by means of at least one calculation prescription into a translation-invariable signal with at least one characteristic value, that the identifying characteristic is weighted with at least one fuzzy association function, that a higher-order fuzzy association function is generated by linking all association functions by means of a calculation prescription consisting of at least one rule, that a sympathetic value is determined from the higher-order fuzzy association function, that the sympathetic value is compared with a threshold value and that, as a function of the result of this comparison, a decision is made regarding the association of the identifying characteristic with a defined class of identifying characteristics.

Testing the identifying characteristic regarding a defined geometric contour, and/or a relative arrangement with at least one further identifying characteristic of the material preferably takes place in that at least one background reference variable and at least one mask reference variable are stored in the memory, wherein the background reference variable represents at least one property of the material to be evaluated in at least one portion of an area of the vicinity surrounding the identifying characteristic, and wherein the mask reference variable represents the geometric contour of the identifying characteristic or the

relative arrangement of several identifying characteristics among each other, that in the course of testing the material a difference value, at least of the expected range, is formed from the first electrical signal made available by the image sensor and the background reference variable, that the actual position of the identifying characteristic is derived from comparing the difference value with the mask reference variable, and that for the qualitative evaluation of the material the portion of the material to be evaluated, which results from the actual position of the identifying material, is blanked out.

The adaptation of the first electrical signal to the color perception of the human eye takes place in that the RGB signal made available by the image sensor at every observation time is considered to be a vectorial output signal, wherein the coefficients of the RGB signal vector are multiplied with a correction matrix which is quadratic in particular, so that all portions of the first electrical signal represented in a signal channel are approximated to the color perception of the human eye. For one, by multiplying the RGB signal vector by a correction matrix, a relatively accurate intercalation of all print colors in a basically arbitrary color range is achieved. Moreover, a matching of the RGB signal vector by means of the multiplication with the correction matrix can be easily realized by means of data technology, so that an implementation into an actual system is possible even with large amounts of RGB signals which are made simultaneously available by a multitude of pixels of the image sensor.

The coefficients of the correction matrix are of course of decisive importance for the quality of the proposed correction of the RGB signals since, depending on the selection of these coefficients, the RGB signal vectors are transformed in different ways. For example, the coefficients of the correction matrix can consist of empirical values. They are stored in a data memory.

For matching the coefficients of the correction matrix variably to different side constraints, for example regarding the color camera used, the illumination conditions, or the lenses used, an iterative approximation algorithm is proposed. A reference color chart, for example an IT8 chart with 288 color fields, is preset for performing this approximation algorithm. The different reference colors are represented in the color fields. Moreover, the assignment of the different reference colors to a suitable color range, for example the CIELAB color range, is known. From these preset CIELAB values for the various reference colors of the reference color chart it is possible by means of known transformations to calculate corresponding reference variables for the three signal channels. Thus, a reference color chart is preset as the input value for the approximation algorithm, and for each reference color a vector with a reference variable for each color channel as a desired result of the conversion. In the course of performing the approximation algorithm for the determination of the coefficients of the correction matrix, the reference color chart is recorded by means of the image sensor of the color camera, and an RGB signal vector is determined for each

color field. The difference between these RGB signal vectors of the color camera and the vector with the preset reference variables corresponds to the difference between the color perception of the human eye and the sensitivity distribution of the color camera,

In order not to have to calibrate the illumination source to a standard light source when using respective camera systems, it is possible to perform a further correction step. In this correction step the coefficients of the RGB signal vectors are converted in such a way that the result corresponds to those RGB signal vectors which would be obtained when illuminating the observed area by means of standard light. The color correction values for matching the RGB signal vectors to different illumination sources and changes can be advantageously calculated in the following way.

At present, the standard light D50 is still being used in printing technology. By specifying the illuminant D50 it is possible to adapt Rec. 709 to D50 standard light by means of a conversion so that the non-linear RGB signal vectors behave as if the object to be tested were illuminated by means of D50 illumination. It is possible by means of the proposed method to match the RGB signal vectors iteratively to the CIELAB color range without an actual standard illumination being necessary. This method has the advantage that in case of an expected change of the specified standard light a match can be immediately provided.

The starting point of the iteration is a correction matrix whose coefficients have been preset as the initial values. These initial values can either be selected purely

accidentally, or corresponding to defined empirical values. In the first iteration step this correction matrix is now multiplied by all RGB signal vectors made available by the image sensor, and the corrected RGB vectors thus obtained are temporarily stored in a data memory. Subsequently the coefficients of the correction matrix are slightly changed, and the multiplication is again performed. The change of the coefficients of the correction matrix is respectively only performed if the corrected RGB signal vectors approximate the vectors with the preset reference variables.

The approximation of the corrected RGB signal vectors to the vectors with the preset reference variables is weighted for each iteration step in order to be able to decide by means of this weighting whether the change of the coefficients of the correction matrix performed made in this iteration step is to be accepted or discarded. An advantageous weighting method provides that for each color field of the reference color chart the difference value between the corrected RGB signal vector and the vector with the preset reference values for this color field is determined and the sum of all these difference values is added. The change of the correction coefficients of the correction matrix in the actual iteration step is only accepted if the sum of all difference values in this actual iteration step has become smaller in comparison to the sum of all difference values in the previous iteration step. But if the sum of all difference values has become greater because of the change of the coefficients of the correction matrix in the previous iteration step, the change of the coefficients is discarded. By means of this summary consideration of the

difference values of all reference colors it is easily possible that the difference between individual reference colors is increased during an iteration step. However, as a whole the minimization of the difference values is dependably assured over all signal channels.

A further problem in connection with camera systems is the correct setting of the color balance, i.e. the correct weighting of the various signal channels in respect to each other. In order to adjust the color balance of the individual signal channels relative to each other, the coefficients of each RGB signal vector can each be multiplied with a correction factor which is a function of the signal channel. At the same time a correction factor is added to each RGB signal vector. This correction of the three signal channels of each RGB signal vector corresponds to a linear displacement of the individual coefficients of the RGB signal vectors.

A particularly good color balance is achieved if the correction vector and the correction vectors which are a function of the signal channels are selected in such a way that the corrected RGB signal vectors obtained by the application of the correction by means of the correction vector, and the correction factors for the two fields with the reference gray values black and white, substantially correspond exactly to the vectors with the preset reference variables of these two color fields. In other words, this means that the linear displacement of the RGB signal vectors is selected to be such that corrected results are obtained for the two reference gray values black and white which correspond to the color perception of the human eye.

Preferably this linear displacement is applied to all RGB signal vectors, so that brightness and contrast are automatically also corrected over the entire color spectrum.

When using color cameras, color distortions and a reduction of intensity, in particular at the edges of the camera images, can occur. These distortions are generated by the optical devices used, for example the lenses used. A so-called shading correction can be employed for correcting this intensity reduction. To this end, correcting factors as a function of the signal channel are specified for each pixel. By multiplying these pixel-dependent correction factors with the coefficients of the RGB signal vectors it is possible to compensate the pixel-specific color distortions or a reduction of the intensity because of the structural type in the various areas of the image sensor.

For example, it is possible to detect these pixel-specific, signal channel-dependent correction factors experimentally in a simple manner in that the observed area of the color camera is lined with a homogeneous material, in particular with a homogeneous white material, and an RGB signal vector is determined for each pixel by means of the camera. Then that RGB signal vector having the highest value coefficients and which therefore represents the brightest location in the observed area is filtered out of these RGB signal vectors. However, since the observed area has been lined with a homogeneous colored material, all pixels should substantially provide identical RGB signal vectors. Therefore the respective differences are based on color distortions or a reduction in intensity as a result of the structural type. To compensate this, correction factors are

now selected for each signal channel of each individual pixel, which see to it that in the course of recording the homogeneous colored material all RGB signal vectors correspond to the RGB signal vector at the brightest location in the observed area.

Color distortions in particular depend greatly from the illumination conditions in the observed area. To prevent error sources based on a change of the illumination conditions, the illumination during the experimental determination of the pixel-specific, signal channel-dependent correction factors of the illumination should therefore correspond to the illumination during the subsequent employment of the camera system.

In many cases of the application of the method for matching the first electrical signal to the color perception of the human eye, the corrected RGB signal vectors obtained by the correction of the RGB signal vectors originally made available by the color camera are employed for controlling the separate signal channels of a color monitor. Here, the representation of the colors on the color monitor also creates the problem that the representational characteristics of most color monitors do no correspond to the color perception of the human eye. This is based in particular on the fact that the brightness behavior of the color monitor as a rule is not linear, i.e. the intensity of the light produced at the color monitor is a non-linear function of the electrical input signals arriving at the color monitor, in this case the RGB signal vectors. In other words this means that, in the case where the RGB signal vectors which had been corrected to match the color perception of the human eye are

merely transmitted to the color monitor and are displayed there without taking the non-linearity of its brightness behavior into consideration, undesired distortions in the color image occur on the color monitor. In that case a dependable qualitative evaluation of a material represented on the color monitor, in particular a material with an identifying characteristic, is then objectively not possible.

To prevent such color distortions in connection with the representation on a color monitor, the coefficients of the corrected RGB signal vector which had been used as a basis can each be raised to a higher power by a factor gamma. By means of this non-linear conversion of the coefficient of the corrected RGB signal vector it is possible to compensate the non-linearity of the brightness behavior of most color monitors. It is necessary for most color monitors to select a value in the range between 0.3 and 0.5, in particular approximately 0.45, for the factor gamma.

In the method for testing the color image for a color deviation from the reference image the processing of the stimulations in connection with human color perception is simulated. For reproducing the three cone types of the human eye with their differing spectral sensitivity, a signal vector is made available by each pixel for the color image recorded by the color sensor - as already mentioned -, whose coefficients preferably represent three signal channels separated from each other. Each one of the three signal channels has a characteristic spectral sensitivity. The two receptive fields representing the second stage of color processing in human vision are simulated by an appropriate linkage of the three separate signal channels. The red/green

field of human color perception represents the first compensation color channel in the technical model. The output signal of the first compensation color channel is generated by the linkage of the portion of the signal vector in the first signal channel with the portion of the signal vector in the second signal channel. Linkage takes place by means of a calculation prescription consisting of at least one arithmetic rule. The blue/yellow field is created in the technical model by the linkage of the portion of the signal vector in the third signal channel with a combination of the portions from the first and second signal channel. In the technical model, the blue/yellow field corresponds to the second compensation color channel. The output signal of the second compensation color channel is generated by the above described linkage. Linkage takes place by means of a second calculation prescription consisting of at least one arithmetic rule. For evaluating the signal vector of the tested pixel, a classification of the output signals of the two compensation color channels takes place in the next step. By means of this it is determined whether the signal vector of the tested pixel, and therefore in the end also the color image, corresponds to a defined class, by means of which a good/bad classification can be made.

For the principle of the method it is of negligible importance in which spectral range the signal channels of the method operate, as long as they are signal channels of different spectral sensitivity. It is advantageous if the signal channels correspond to the three basic colors of the RGB model, namely red, green and blue, because with this use is made of a widely distributed color model. The spectral

sensitivity of each signal channel is advantageously matched to the spectral sensitivity of the cone types in the retina of the human eye.

It is of secondary importance for the principle of the invention in which way the two output signals of the compensation color channels are generated. One option lies in that an arithmetic rule of the first calculation prescription provides a weighted difference formation of the portion of the signal vector in the second signal channel from the portion of the signal in the first signal channel, and/or that an arithmetic rule of the second calculation prescription provides a weighted difference formation of the weighted sum of the parts of the first and second signal channel from the portion of the third signal channel.

Preferably at least one signal in at least one compensation color channel is subjected to a transformation prescription after and/or prior to the linkage, in particular a non-linear transformation prescription. A transformation has the particular advantage that the digital character of electronically generated color images can be taken into consideration. By means of the transformation prescription it is also possible to transform a signal from the color range into a range, in which the stimulation of the cones can be described. Preferably, the signals in both compensation color channels are subjected to a transformation.

Since the receptive fields in human vision are characterized by a low pass behavior it is sensible to filter at least one signal in at least one compensation color channel by means of a low pass filter. Preferably the output

signal of every compensation color channel is filtered by means of a low pass filter.

Preferably the method has a learning mode and a working mode. In particular, an evaluation device processing the signals from the image sensors can be switched between these two operating modes, i.e. the learning mode and the working mode. During the learning mode at least one reference image, for example the recording of at least a single printed sheet, is checked pixel by pixel, and the output signals from the two compensation color channels generated by the reference image are stored in a data memory as a second electrical signal constituting a reference variable. In actuality this means that a signal vector of the reference image is made available, for example, in three signal channels, that the portions of the signal vector made available in each signal channel are matched in respect to perception and that these portions are thereafter linked with each other corresponding to the compensation color model. Then the output signals from each compensation color channel are stored pixel by pixel in the data memory. In the subsequent working mode the output signals created by a color image to be tested of the respective pixel are compared with the corresponding values stored in the data memory in the form of reference variables, and a classification decision is then made.

In order to take permissible color fluctuations of the color image, as well as fluctuations of the conditions during the taking of the image, into consideration, it is practical for the values stored in the data memory to be formed by several reference data sets, so that a permissible tolerance

window is fixed in the data memory for each value, within which an output signal value of a compensation color channel generated during the image testing is permitted to fluctuate. In this case the reference variable of the output signal of a compensation color channel can be determined for example by arithmetic average value formation from the individual values, wherein the individual values result from the reference data sets. For example, the tolerance window can be determined by the minimum and maximum values of, or by the standard deviation from, the output signals generated by the tested reference images of the compensation color channel of each pixel.

The method for checking the identifying characteristic regarding its association with a defined class of identifying characteristics preferably proceeds through the following substantial method steps: characteristics formation, fuzzyfication, interference, de-fuzzyfication and decision regarding a class association.

During the characteristics formation the first electrical signal made available by the image sensor is converted by means of at least one calculation prescription into a translation-invariable signal within a range of characteristics. The aim of the characteristics formation is the determination of those values by means of which typical signal properties of the color image are characterized. The typical signal properties of the color image are represented by so-called characteristics. In this case the characteristics can be represented by values within the characteristic range or by linguistic variables. A signal is created by means of the conversion of the first electrical

signal in the characteristic range, which consists of one characteristic value or of several characteristic values.

The association of a characteristics value with a characteristic is described by at least one fuzzy association function. This is a soft, or also fuzzy association wherein, as a function of the value of the characteristic value, the association of the characteristic value with the characteristic exists within a standard interval between 0 and 1. The concept of association leads to a characteristic value no longer being either wholly or not at all affiliated with a characteristic, but instead it can take on a fuzzy association which lies between the Boolean logical values 1 and 0. The just described step is called fuzzyfication. Thus, during fuzzyfication, substantially a conversion of a hard characteristic value into one or several fuzzy associations takes place.

In the course of interference, a higher level association function is generated by means of a calculation prescription consisting at least of one rule, wherein all association functions are linked together. As a result a higher order association function is obtained for each window.

In the course of de-fuzzyfication a numerical value is determined from the higher order association function formed from the interference, which is also called a sympathetic value. During the decision regarding the class association a comparison of the sympathetic value with a previously fixed threshold value takes place, by means of which the association of the window to a specified class is decided.

In this case the threshold value forms a further reference variable contained in the second electrical signal.

It is of secondary importance for the basic progression of the method of which type the characteristic values in the characteristic range are. For example, in the case of time signals it is possible to determine their mean value or variation as the characteristic values. If the requirement is made on the method for checking the identifying characteristic for its association to a defined class of identifying characteristics that it is to process the color images free of errors, regardless of the respectively prevailing signal intensity, and if furthermore small, but permissible fluctuations in the color image are not to result in interferences, it is sensible to perform the conversion of the first electrical signal from the two-dimensional local range by means of a two-dimensional spectral transformation. Examples of a suitable spectral transformation are respectively two-dimensional Fourier, Walsh, Hadamard or circular transformations. Translation-invariable characteristic values are obtained by means of the two-dimensional spectral transformation. The value of the spectral coefficients obtained by means of a spectral transformation is preferably used as characteristic value.

The association functions are preferably unimodal potential functions. The higher order association function is preferably a multi-modal potential function.

It is advantageous to parametrize at least one association function. If the association function has positive and negative slopes, it is advantageous if the

parameters of the positive and negative slopes can be separately determined. A better matching of the parameters with the data sets to be examined is assured by means of this.

In accordance with a particularly preferred exemplary embodiment the method is again divided into two different modes of operation, namely into a learning mode and into a working mode. If the association functions are parametrized, it is possible in the learning mode to determine the parameters of the association function from measured data sets. In the learning mode the parameters of the association functions are matched with so-called reference images, i.e. in the learning mode an association of the characteristic values resulting from the reference images with the corresponding characteristics is derived by means of the association function and its parameters. In the subsequent working mode the characteristic values resulting from the subsequently measured data sets are weighted with the association functions whose parameters had been determined in the learning mode, by means of which an association of the characteristic values of the now measured data sets with the corresponding characteristics is established. Thus, the parameters of the association functions are determined by means of measured reference data sets because of the division of the method into a learning mode and a working mode. The data sets to be tested are weighted in the working mode by the association functions determined in the learning mode and are evaluated.

Furthermore, a rule by means of which the association functions are linked with each other preferably is a conjunctive rule within the meaning of an IF..THEN linkage.

The generation of the higher order fuzzy association functions is preferably divided into the following partial steps: premise evaluation, activation and aggregation. In the premise evaluation an association value is determined for each IF portion of a rule, and during activation an association function for each IF...THEN rule. Thereafter, during aggregation the higher order association function is generated by overlaying all association functions created during activation.

It is advantageous to perform the sympathetic value determination in accordance with a focus and/or maximum method.

Checking the identifying characteristic for a defined geometric contour and/or a relative arrangement in respect to at least one further identifying characteristic of the material is based on the basic idea of additionally letting known information regarding this identifying characteristic enter into the evaluation in the course of evaluating a positionally variable identifying characteristic, for which the optical properties, for example the reflection capability, does not suffice for a sufficiently dependable identification. A premise in this case is that the positionally variable identifying characteristic, for example a colored window thread, differs in its optical properties, for example by its gray value, at least in partial areas sufficiently from the remaining material to be inspected, for

example the print image surrounding the identifying characteristic, that there is at least no complete correspondence between the identifying characteristic and the print image. Thus, for determining the position of the positionally variable identifying characteristic, additional information regarding the contour, known per se, of the identifying characteristic or the relative arrangement of several identifying characteristics contained in the print image are evaluated. This additional information is then stored in a mask reference stored in the data memory in regard to every material to be evaluated, which represents the geometric data in a suitable form.

Furthermore, a background reference variable has been stored as a reference in the data memory, which represents the optical properties of the print image in at least a part of an area surrounding the identifying characteristic. The optical properties of the background reference variable must differ, at least slightly, from the optical properties of the identifying characteristic to be detected. In the course of testing the material a differential value, which represents a differential image at least of the expected area, is then formed from the actual first electrical signal made available by the image sensor and the background reference variable.

Substantially all characteristics of the print image, which correspond in their optical properties to the background reference variably, are blanked out of the differential image by means of the difference formation. Only positionally variable areas of the identifying characteristic and also other elements, such as printing errors or deviations of the edges, are represented in the

differential image because of their deviation from the background reference value, wherein the areas of the positionally variable identifying characteristic have particularly high amplitudes.

As soon as the differential values are available, the differential values are compared with the mask reference variables of the mask reference, and a conclusion regarding the actual position of the identifying characteristic is drawn from the result of the comparison. This method step is based on the reflection that the differential image is substantially determined by the representation of the positionally variable identifying characteristic, so that a conclusion regarding the actual position of the positionally variable identifying characteristic can be drawn from the considerable overlapping of the mask reference and the differential image. If no sufficient overlap between mask reference variables and differential values can be determined because of other error effects this is harmless, since this merely leads to an error indication in the course of the print image check, for example, and to the removal of the respective printed sheet.

Preferably the areas of the print image resulting from the actual position of the identifying characteristic are blanked out during the subsequent qualitative evaluation of the material, so that interferences with the checking of the print image because of the positionally variable arrangement of the identifying characteristic are excluded.

The detection of the positionally variable identifying characteristic can be improved during the performance of this method in that a threshold for binary formation is stored in

the data memory. After the differential image was formed from the first electrical signal and the background reference variable, all image data, whose values lie below the threshold for binary formation, can be filtered out of the differential image. This means that only those image points remain in the differential image which differ with considerable significance from the remaining print image, so that the mostly other deviations, for example printing errors or edge deviations, can be blanked out of the differential image.

The procedure in the course of determining the position of the positionally variable identifying characteristic in the actual print image can be such that the mask reference is shifted until a maximum overlap between the mask reference and the differential image results. Various mathematical evaluation methods can be employed for this for evaluating the overlap between the mask reference and the differential image and for finding the appropriate overlap maximum. It is of course possible to provide the evaluation of the overlap by a visual check by sufficiently trained checking personnel which, however, because of the high costs of personnel and the low processing speed is not sufficiently economical in most cases. Therefore the calculation of the overlap between the differential image and the mask reference should take place by using suitable mathematical operations by means of methods of electronic data processing, if possible.

A possibility for evaluating the overlap between the mask reference and the differential image consists in the calculation of foci in accordance with the optical distribution of the image points in the differential image,

and in comparing these foci with the focus of the mask reference. Maximum overlap results when the sum of the focus differences between the mask reference and the differential image is minimized.

A prerequisite for performing this method for testing the identifying characteristic for a defined geometric contour and/or a relative arrangement in respect to at least one further identifying characteristic of the material is the storage of a suitable background reference variable in the data memory. In principle, the background reference variable can be simply preset as a method parameter, for example based on one or several empirical values. However, it is advantageous if the background reference variable is specifically fixed in a learning mode as a function of the respective print image of the material to be tested. Two alternatives of this will be shown in what follows.

In accordance with the first alternative for determining the background reference variable, reference material which does not contain the positionally variable identifying characteristic is used in the learning mode. For example, printed sheets imprinted with bills or stamps which do not have the window thread can be used for this. By evaluating this reference material without the identifying characteristic it is possible to derive the background reference variable.

If reference material without an identifying characteristic is not available, the learning mode can also be performed with reference material containing the positionally variable identifying characteristic. If in the course of evaluating the print image of the reference

material the positionally variable identifying characteristics appear bright in comparison with the surrounding area, a threshold value corresponding to the values of the darkest image points of the identifying characteristic is selected as the background reference variable. In the course of the subsequent testing of the material it is then assumed based on the threshold value that, at least in the expected area, all image points which are darker than the background reference variable are not a part of the positionally variable identifying characteristic. But if in comparison with the surrounding area the identifying characteristic appears dark, a threshold value is selected as the background reference variable whose value corresponds to the brightest image points of the identifying characteristic.

To the extent it is required on the basis of the optical properties of the print image, it is of course possible to define different background reference variables for different areas of the material, so that the positionally variable identifying characteristic is pictured with sufficient significance in the differential image.

Exemplary embodiments of the invention are represented in the drawings and will be described in greater detail in what follows.

Shown are in:

Fig. 1, a block diagram with functional units which are relevant to the method,

Fig. 2, method steps in the course of performing the method for testing the color image for a color deviation from a reference image,

Fig. 3, a schematic representation of the method for testing for color deviations in the recorded color image with a compensation color model,

Fig. 4, a flow chart of the learning and working mode, as well as of the classification,

Fig. 5, a flow diagram of the method for testing the identifying characteristic for its association with a defined class of identifying characteristics,

Fig. 6, a schematically represented differential image in a view from above,

Fig. 7, a differential image in accordance with Fig. 6 following the performance of a binary formation,

Fig. 8, the mask reference for determining the position of the positionally variable identifying characteristic in the differential image in accordance with Fig. 7,

Fig. 9, the overlap between the differential image in accordance with Fig. 7 and the mask reference in accordance with Fig. 8,

Fig. 10, a second mask reference in a schematically represented lateral plan view,

Fig. 11, a second differential image in a schematically represented lateral plan view.

A block diagram with the functional units relevant for the method for the qualitative evaluation of an imprinted material 19 with at least one identifying characteristic is shown in Fig. 1. A color camera 01, which for example has been attached fixed in place in or at a printing press, so that with its image sensor 02 it can record color images of the material 19 to be evaluated, which is moved past the color camera 01, preferably in the course of the running

print process, is connected to an evaluating device 03. The image data recorded by the color camera 01 and evaluated in the evaluating device 03 can be represented, if required, on a color monitor 04, wherein the color monitor 04 can be arranged in or at a control console which is part of the printing press. The testing methods used for the qualitative evaluation of the imprinted material 19 are represented in connection with the evaluating device 03 for example in three parallel signal paths, wherein the testing processes in the respective signals paths take place preferably in the same evaluating device independently of each other. The tests preferably occur at least approximately at the same time, i.e. the test processes at least start at the same time. The test process can start after the evaluating device 03, which operates in at least two modes of operation, has changed from its learning mode 48 into its working mode 49. Respectively one signal path relates to a functional unit 06 for testing at least the color image of the identifying characteristic for a color deviation from the reference image, a functional unit 07 for testing the identifying characteristic for its association with a defined class of identifying characteristics, and a functional unit 08 for testing the identifying characteristic for a defined geometric contour or an arrangement relative to at least one further identifying characteristic of the material 19, wherein each test includes a comparison, performed at a comparison location 11, 12, 13, of the first signal 09, made available by the image sensor 02 of the color camera 01 and suitably processed, with respectively suitably fixed reference variables 16, 17, 18, wherein the reference variables 16, 17, 18 are stored in a

data memory 14, which is part of the evaluating device 03. The respective test results in the individual signal paths are again reported to the evaluating device 03 for the purpose of being stored there. The functional units relevant to the method for the qualitative evaluation of an imprinted material 19 with at least one identifying characteristic can also be implemented in a machine processing the material 19, wherein this machine can preferably be arranged downstream of, but also upstream of, for example a printing press, preferably a sheet-fed printing press, in particular a sheet-fed rotary printing press. The material 19, i.e. a print sheet 19 having, for example, several identifying characteristics, is imprinted in a printing press at a speed of, for example, 18,000 sheets per hour and/or subsequently further processed in the machine processing these print sheets 19 at this speed. In the case where the material 19 is embodied as a web 19 of material, the printing speed or the further processing speed can be 15 m/s, for example. Although the testing processes for evaluating the quality of the material 19 to be processed by the printing press or the machine are calculation-intensive and the movement speed of the material 19 is high, a dependable evaluation is achieved by means of the proposed method. Since the functional units relevant to the method for the qualitative evaluation of an imprinted material 19 with at least one identifying characteristic are arranged in or at the printing press or the machine processing the material 19, the location for making the reference signal available and the location of the test are identical. The color image and its reference image can be recorded by the same functional units, in particular

the same color camera 01, in the same location, and evaluated in the same evaluating device 03.

The following method steps are performed for the qualitative evaluation of the imprinted material 19 and will now be explained by way of example by means of Figs. 2 to 11.

A color image of a material 19, imprinted in color and arranged in the observation area 21, is recorded by means of the color camera 01. The color camera 01 has an image sensor 02, preferably embodied as a CCD chip 02, which converts the image information recorded in the observation area 21 into electronic image data, which form a first electrical signal 09 made available by the color camera 01, or its image sensor 02. In the course of this conversion a signal vector 22 is generated by each one of the light-sensitive pixels of the CCD chip 02. Corresponding to the number of pixels of the CCD chip 02, the color camera 01 makes available a corresponding number of signal vectors 22, identified by means of a counting index, to the evaluating device 03 for further processing.

Preferably each signal vector 22 has three coefficients R, G and B. The coefficients R, G and B correspond to the color values of the three signal channels red, green and blue, wherein the vectorially first electrical signal 09 emitted by a pixel is correlated with the recorded color of the imprinted material 19 at the corresponding position in the observation area 21.

The signal vectors 22, whose counting index is used for describing the arrangement of the respective pixels on the CCD chip 02, constitute raw data for a first correction module 23 for matching the color balance, the brightness and

the contrast. For this purpose, each coefficient R, G, B of the signal vector 22 is multiplied by a signal-dependent correction factor K_1, K_2, K_3. Moreover, to the resulting vector is added a correction vector 24 with the fixed value coefficients a_1, a_2 and a_3. First corrected signal vectors 26 are created by this arithmetic operation, which improve the color balance, the brightness and the contrast of the image data. This goal is achieved in that the signal channel-dependent correction factors K_1, K_2, K_3, as well as the coefficients a_1, a_2 and a_3 of the correction vector 24 have been selected in such a way that, in the course of recording the reference gray values black and white, the signal vectors 22 generated by the color camera 01 are here transformed in such a way that the received corrected signal vectors 26 correspond to those reference variables which result in the vectors from the conversion of the known CIELAB color values.

Thereafter the first corrected signal vectors 26 are provided to a second correction module 27. In the second correction module 27 each first corrected signal vector 26 is multiplied by a quadratic i x i correction matrix 28, wherein i corresponds to the number of coefficients of the corrected signal vector 26, wherein in this case i = 3. The second corrected signal vectors 29 result from this multiplication. The coefficients K_4 to K_{12} of the correction matrix had previously been determined in a suitable iteration process in such a way that the image information contained in the first corrected signal vectors 26 is brought closer to the color perception of the human eye.

Subsequently the second corrected signal vectors 29 are forwarded to a third correction module 31. In the third correction module 31, signal channel-dependent correction factors relating to each pixel have been stored in a data memory 14 which, for accommodating the intensity values which depend from the position of the respective pixels, are multiplied with the coefficients R, G and B. As a result, the second corrected signal vectors 29 of the first pixel are multiplied by the correction factors K_{13}, K_{14} and K_{15} in order to calculate a third corrected signal vector 32 for the first pixel. Preferably this correction of the second corrected signal vectors 29 is performed for all pixels of the image sensor 02.

The third corrected signal vectors 32 are then passed on to a fourth correction module 33. In the fourth correction module 33 the coefficients R, G. B of the third corrected signal vectors 32 are raised to a higher power by a factor gamma and the fourth corrected signal vectors 34 are calculated from this. By raising it by the factor gamma, the non-linear brightness transfer function of a color monitor 04 is taken into consideration, to which the fourth corrected signal vectors 34 are transmitted for display.

As mentioned, the recording of the image signal by an image sensor 02 takes place in signal channels R, G, B which are separated from each other. In the present exemplary embodiment the three signal channels R, G, B are the three signal channels red R, green G and blue B. Each one of the signal channels R, G, B has an adjustable spectral sensitivity. This has the advantage that the spectral

sensitivity of each signal channel R, G, B can be adapted to the spectral sensitivity of the respective cone of the retina of the human eye.

In the course of the method for checking the color image for a color deviation from a reference image, the spectral content of an image is analyzed pixel by pixel. For modeling the two receptive fields red/green and blue/yellow of the human eye, in accordance with Fig. 3 in this method the image sensor signals of the signal channels R, G, B are linked with each other. Prior to the actual linkage by means of the calculation prescriptions 36, 37, each image sensor signal is subjected to a non-linear transformation 41 in the compensation color channels 38, 39. By means of this the digital character of the electronically created recordings is taken into consideration. Each signal is subsequently weighted with a coefficient K_i 42 ($i = 1...4$). It is achieved by this that a mere intensity change of the initial image does not make a contribution to one of the output signals 43, 44 of the compensation color channels 38, 39. The generation of the output signals 43, 44 of the compensation color channels 38, 39 takes place analogously to the generation of the signals of the receptive fields in the human retina. This means that a linkage of the signal channels R, B, G by means of the calculation prescriptions 36, 37 is performed corresponding to the linkage of the cones of the human retina. For creating the output signal 43 of the red/green compensation color channel 38, the image sensor signals of the red signal channel R and the green signal channel G are linked together by means of the first calculation prescription 36. For generating the output

signal 44 of the blue/yellow compensation color channel 39, in the present exemplary embodiment the image sensor signal of the blue signal channel B is linked with the minimum 46 of the image sensor signals of the red signal channel R and the green signal channel G by means of the calculation prescription 37. The receptive fields of the human retina are distinguished by a low pass behavior. Accordingly, in the present exemplary embodiment the signals obtained by linkage are subjected to low pass filtering 47, for example by means of a Gauss low pass filter.

Fig. 4 shows the actual testing of the imprinted material 19, which takes place in two stages, namely in a learning mode 48 and a subsequent working mode 49. The aim of the learning mode 48 is the generation, pixel by pixel, of reference variables for use as reference data values, which are compared in the subsequent working mode 49 with the output signals 43, 44 of the compensation color channels 38, 39 of the corresponding pixels. In the learning mode 48 the image contents of a reference image 52, or of several reference images 52, are analyzed in that the image contents of each pixel are introduced into three signal channels R, G, B, and a subsequent matching in accordance with the perception of the image signals of each signal channel R, G, B is performed, and thereafter further processing of the image sensor signals is performed in accordance with the previously described compensation color method. The output signals 43, 44 of the compensation color channels 38, 39 obtained for each pixel are then stored in a data memory 14. In order to also take permissible fluctuations of the reference images 52 into consideration it is useful if

several reference images 52 are considered in the learning mode 48. It is possible by means of this for the stored reference variables of each pixel to have a permissible fluctuation tolerance. The fluctuation tolerance can be fixed either by minimum/maximum values or the standard deviation from the received data of the image contents of the reference images 52 of each pixel.

Then, in the working mode 49 a pixel by pixel comparison of the output values 43, 44 of the compensation color channels 38, 39 of an inspection image 53 with the reference variables from the data memory 14 takes place. This comparison can be performed by means of a linear or non-linear classification device 54, in particular by means of threshold value classification devices, Euclidic distance classification devices, Bayes classification devices, fuzzy classification devices or artificial neuronal networks. A good/bad decision takes subsequently place.

Fig. 5 shows a flow diagram of the signal evaluation in the method for checking the identifying characteristic for its association with a defined class of identifying characteristics.

First, a grid of M x N windows 56 is placed over the entire color image to be checked, wherein M, N > 1. Each window 56 advantageously consists of m x n pixels, with m, n > 1. A square window 56 of N x N windows 56 is preferably selected, wherein each window 56 consists of n x n pixels. In the testing process the signal of each window 56 is checked separately.

The two-dimensional color image of the local range is transformed by means of one or several two-dimensional

spectral transformations 58 into a two-dimensional image in the frequency range. The obtained spectrum is called a frequency spectrum. Since in the present exemplary embodiment this is a discrete spectrum, the frequency spectrum is also discrete. The frequency spectrum is constituted by the spectral coefficients 59 - also called spectral values 59 -.

The sum formation 61 of the spectral values 59 takes place in the next method step. The sum of the spectral values 59 is called spectral amplitude value 62. In the present exemplary embodiment, the spectral amplitude values 62 constitute the characteristics values 62, i.e. they are identical to the characteristics values 62.

The characteristics selection 63 follows as a further method step. It is the goal of the characteristics selection 63 to select those characteristics 64 which are characteristic of the image content of the color image to be checked. Characteristic spectral amplitude values 62, which define the characteristic 64 by their position in the frequency range and by their amplitude, as well as linguistic variables, such as "gray", "black" or "white", for example, are possible as characteristics 64.

In the now following method step, the fuzzyfication 66, the association of each spectral amplitude value 62 to a characteristic 64 is determined by a soft or fuzzy association function 67, i.e. weighting is performed.

If in a learning mode the association functions 67 are to be matched to reference variables stored in the form of reference data sets, it is useful for the association function 67 to be designed as parametrized monomodal, i.e.

one-dimensional, potential functions, in which the parameters of the positive and negative slopes can be separately matched to the reference variables to be tested. In the working mode following the learning mode, the data sets of the image contents from which the characteristics values 62 of the color images to be checked result, are weighted with the respective association functions 67 whose parameters had been determined in the previous learning mode. This means that for each characteristic 64 a sort of SHOULD BE - IS comparison takes place between a reference data set, expressed in the parameters of the association functions 67, and the data set of the color image to be checked. A soft or fuzzy association is produced between the respective characteristics value 62 and the characteristic 64 by the association functions 67.

In the next method step, the interference 68, a substantially conjunctive linkage 69 - also called aggregation 69 - of all association functions 67 of the characteristics 64 takes place, by means of which a higher order association function 71 is created.

The next method step, defuzzyfication 72, determines a concrete association value 73, or sympathetic value 73, from the higher order association function 71. In the course of the classification 74 this sympathetic value 73 is compared with a previously set threshold value 76, so that a classification statement can be made. The threshold value 76 is set either manually or automatically. Setting of the threshold value 76 also takes place in the learning mode.

The method for checking the identifying characteristic for a defined geometric contour and/or for a relative

association with at least one further identifying characteristic of the material substantially takes place during the following steps.

In accordance with Fig. 6, a differential image 77 had been formed in the course of checking printed sheets, for example imprinted with bills 19, wherein only a portion of the differential image 77 in the area of a bill 19 is represented in Fig. 8. It can be seen in Fig. 6 that the normal print image of the bill 19 has been blanked out of the differential image 77 and only those areas of the print image which significantly differ from the background reference value are represented as dark fields in the differential image. In a strip-shaped expected range 78, indicated by dashed lines, the position of, for example, an identifying characteristic 79 placed into the printed sheet can vary, in particular an incorporated window thread 79 which in accordance with its perforations is shown in five dark fields 79.

Besides the five dark fields 79 which can be seen in the representation of the window thread 79, still further perforation characteristics are formed in the differential image 77 as irrelevant dark fields 81 which had been created by print errors 81, for example.

Fig. 7 shows the differential image 77 following a suitable binary formation, by means of which the irrelevant dark fields 81 were filtered out. As a result, only the dark fields 79 stemming from the window thread 79 stand out significantly in the differential image 77.

Fig. 8 represents a mask reference 82 in its geometric shape. The data for the width 83 and the length 84 of the

window thread perforations 79 have been stored in the mask reference 82. Furthermore, values of the distance 86 between the window thread perforations 79 and the number of window thread perforations 79 per bill 19 are stored in the mask reference 82.

As schematically indicated in Fig. 9, during the evaluation the mask reference 82 is shifted by means of technical data operations in relation to the differential image 77 until a maximum overlap between the mask reference 82 and the dark fields 79 in the differential image 77 results. Once this maximum overlap has been achieved, it is possible to draw conclusions regarding the actual position of the window thread 79 in the print image from the distances 87, 88 which, for example, result from the actual positions in the X and Y directions of the mask reference 82 in relation to the edges of the bill 19, so that during a subsequent check of the print image the areas of the window thread perforations 79 can be blanked out.

Fig. 10 shows a second mask reference 89, which represents dark fields 91 corresponding to eight window thread perforations 91 in the course of check a bill 19 on a concavely curved support surface.

Fig. 11 schematically represents a differential image 92, in which the window thread perforations 91 are shown in dark fields 93, for example in window threads 93. In this case the dark field 94 was caused by a print error 94 and not by a window thread perforation 91. Furthermore, a window thread perforation 91 in the center is not pictured because of the insufficient color difference between the background and the window thread 93.

For simplifying the comparison between the mask reference 89 and the differential image 92 for position finding, the mask reference 89 is projected onto a projection line 96, and the light-dark distribution resulting from this is compared with the light-dark distribution resulting from the projection of the reference image 92 onto a projection line 97. By means of this one-dimensional comparison of the light-dark distribution it is possible to determine the position of the window thread 93 in one direction.

List of Reference Symbols

01	Color camera
02	Image sensor, CCD chip
03	Evaluating device
04	Color monitor
05	-
06	Functional unit
07	Functional unit
08	Functional unit
09	Signal, electric, first
10	-
11	Comparison location
12	Comparison location
13	Comparison location
14	Data memory
15	-
16	Reference variable
17	Reference variable
18	Reference variable
19	Material, bill, stamp, printed sheet, web of material
20	-
21	Observation area
22	Signal vector
23	Correction module, first
24	Correction vector
25	-
26	Signal vector, first, corrected

27	Correction module, second
28	Correction matrix
29	Signal vector, second, corrected
30	-
31	Correction module, third
32	Signal vector, third, corrected
33	Correction module, fourth
34	Signal vector, fourth, corrected
35	-
36	Calculation prescription
37	Calculation prescription
38	Compensation color channel
39	Compensation color channel
40	-
41	Transformation
42	Coefficient K_i ($i = 1 \ldots 4$)
43	Output signal (38)
44	Output signal (39)
45	-
46	Minimum
47	Low pass filtering
48	Learning mode
49	Working mode
50	-
51	-
52	Reference image
53	Inspection image
54	Classification device
55	-
56	Window, image window

57	-
58	Spectral transformation
59	Spectral coefficient, spectral value
60	-
61	Sum formation
62	Spectral amplitude value, characteristics value
63	Characteristics selection
64	Characteristic
65	-
66	Fuzzyfication
67	Association function
68	Interference
69	Conjunctive linkage, aggregation, conjunctive calculation prescription
70	-
71	Higher order association function
72	Defuzzyfication
73	Association value, sympathetic value
74	Classification
75	-
76	Threshold value
77	Differential image
78	Expected range
79	Dark field, window thread, recognition characteristic, window thread perforation
80	-
81	Dark field, print error
82	Mask reference
83	Width
84	Length

85	-
86	Distance
87	Distance
88	Distance
89	Mask reference, second
90	-
91	Window thread perforation, dark field
92	Differential image
93	Dark field, window thread
94	Dark field, print error
95	-
96	Projection line
97	Projection line

RGB	Coefficient, signal channel
K_1, K_2, K_3	Correction factor
K_4 to K_{12}	Coefficient
K_{13}, K_{14}, K_{15}	Correction factor
a_1, a_2, a_3	Fixed value coefficient
gamma	Higher power factor